tific demonstration. It is surprising that the disadvantages under which a horse labors should not have engaged the attention of scientific men long ago.

The manual training schools of this and of every other country teach all the arts from needlework to blacksmithing. There are schools for farming and all the professions. But there is not so much as a text-book on wagon and carriage building. If a boy becomes a wagon-maker, he makes no study of the economical application of force to move it. He cuts his lumber and welds his iron after the old methods, except as he may modify them to suit his taste in style. If the horse can be hitched to the vehicle in a manner which will lighten his load, the maker of the vehicle does not know it.

In the simple matter of so hitching a horse to a wagon as to lighten his load we encounter scientific problems based on scientific principles, and yet almost everybody treats the subject as one of common character. We have in England large and old-established wagon-making firms that never knew what it was to work to a scale drawing. What would the world think of an engineering firm that worked on such a basis?

I am sorry to say that in all my experience I have never met a wagon or a carriage builder who had an intelligent conception of the fundamental principles of economical haulage. The builders rely, sad to say, too much upon the users of vehicles. The latter very naturally come with conflicting statements, and well they may, because of the many different conditions under which they work their vehicles. At present it seems to make no difference to the coach-builder whether the particular vehicle he is making is to be used in a hilly or a flat country. The fact is, he does not know that there is a difference, or at least what that difference is.

There are all sorts of conflicting notions upon the theory of long and short wheel-based carriages, and very different results are obtained from long and short vehicles, but nobody seems to know exactly why. In fact, there is nothing but chaos as between the ideas of theorists and practical men. From what I gather, the coach-builders owe their advancement to coachmen, and the latter, for want of scientific knowledge, or a knowledge of facts, have had to work largely in the dark. Of necessity they were compelled to act upon a knowledge of what they saw and not upon scientific principles. The driver finds that a particular angle of trace is better or worse than another, taking the whole day's work into

consideration; but if he goes into another part of the country he probably finds that the angle should be varied. He learns by observation that it is better or worse for the horse if a two-wheeled cart is loaded in different ways, according to the circumstances. He is correct in his conclusions, and yet engineers say that "to transport a given load over a given distance in a given time, the work done in foot pounds is just the same." These engineers differ from the driver; nevertheless, the engineers are wrong and the driver is right, so far as the understanding of the latter goes. In spite of what engineers have often said upon the question of "work done," I resolutely maintain that the work done in *pushing* a wheelbarrow, with a given load over a given distance, is *not near* so great as when the same vehicle is *pulled.*

Again, we have men of supposed scientific information who build hand-carts to be hauled by costermongers. We would not like to admit that these men know more about the principles of mechanics than we do; and yet they very correctly refuse to haul their carts by the handles. These men know no more about the principles of mechanics than the carts they haul, but they must be credited with knowing which method of hauling is easiest for them. I have made it my pleasing duty to investigate their practices, and when I have come to plot out all the forces exerted by them, as well as by nurse-girls with their perambulators and by boys with their go-carts, I have found that nearly all of them were acting in perfect harmony with natural law and common sense. But we, who boast of our scientific knowledge and of our humanity, in yoking our horses to their loads act in direct opposition to natural law and common sense. No costermonger would suffer himself to work under such conditions as we ignominiously impose upon our horses. Surely, in this respect, what is good for man is good for beast.

As I have already stated, I am convinced that fifty per cent. of the energy of a horse is wasted by the unscientific method of attaching him to the vehicle which he is required to haul. I was led to the investigation of this subject by a very simple incident, as Isaac Newton was led to the discovery of the law of gravitation, if I may be pardoned the reference, by noting the fall of an apple to the ground. Two horses were being cruelly beaten by their driver in the streets of London, because they had great difficulty in moving their load, which, under ordinary conditions, they could have moved without much effort. Observing the conditions, I stopped and asked myself the question, from a mechanical point of

view: "Are the horses attached to the load in a manner which will give them the greatest possible control over it?" I at once answered my question in the negative. "No, they are not, because they are relying almost entirely upon their own unaided weight for the force they can exert, and they are unable, by reason of the direction of their traces, to exert anything like their full natural strength."

Let me illustrate by an example. Suppose the horse replaced by a windlass placed on a smooth floor. The hauling rope is passed under pulley *A* and over that of *B*, and attached to a heavy weight, *W*—not forgetting that the windlass is resting on a smooth surface, neither pinned nor weighed down. The weight *W* being heavy and the road smooth, the most natural thing in the world to expect would be that the windlass would slip, or slide, toward the weight.

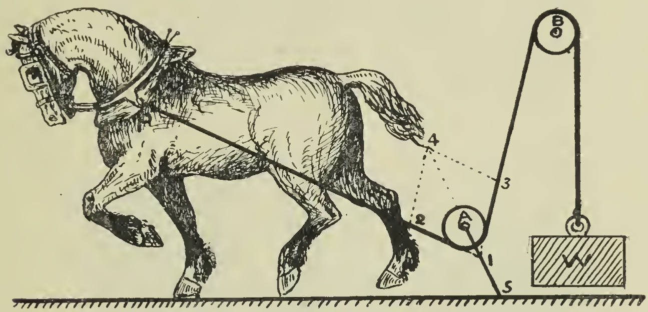


FIG. 1.

What would you think of the man who would thereupon pick up a sledge-hammer and smash the machine because it would not haul the load? Would you not look upon him as possessing less than normal sense? I am sure you would. But this represents, as nearly as possible, what was being done with the poor horses referred to, and what is being done daily to thousands of others. The unfortunate brutes were being whipped because the load had a greater mechanical advantage than they had, and through no fault of theirs; it was the fault of the world's imperfect knowledge of animal mechanics, or of "cause and effect." The horses were unduly and wastefully straining every nerve, because they had not sufficient weight to give them grip to start their load, and the method of attachment was such that they could not get the grip. "They would if they could, but, poor brutes, they can't."

Let me give a further illustration of my meaning. If we attach

an elephant to a large van in such a manner as we attach our horses, the load and the gradient might be such that he could not possibly haul it. But, if we rid him of the fettered system, and permit him to perform his task as instinct and common sense dictate, both to man and beast, he will go behind the load where he can place his trunk beneath the van and lift considerable weight. Besides, he will thrust with his head, as depicted in the sketch

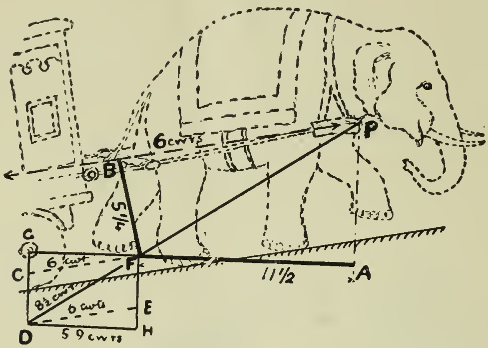
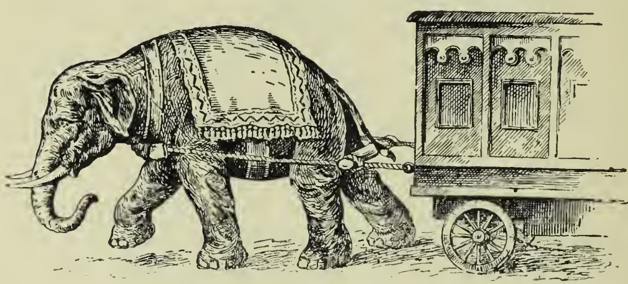


FIG. 2.



From which diagram Fig. 2 is made.

before you. He would manage *better* in *front* if he could only secure the lift at the vehicle.

If you plot out the forces in the two cases you will observe that, when yoked like a horse, the more the elephant pulls the more weight he takes from his fore legs and transfers it to his hind legs. Therefore, we find ultimately when he is thus exerting his maximum effort the whole of it is measured by the strength of the hind legs alone. On the other hand, if he applies his forces as he thinks best, he can not only exert all the muscular power of his hind legs, but also that of the fore legs. Surely no one will doubt his power

to exert a much greater force by the combined efforts of four legs than of two. To deny this one must contend that a man can bear as much weight upon his back when standing on one leg as when standing on both.

It is manifestly impossible for a man to lift so great a weight when it is placed on one side of his body as he could if the weight were centrally under or over him, because, when lifting to his ut-

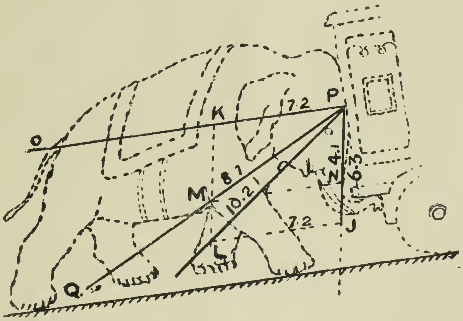
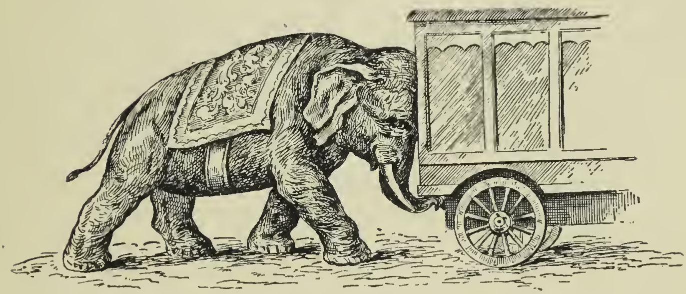


Fig. 3.



From which diagram Fig. 3 is made.

most, he must of necessity support not only all his own weight on the *one leg* nearest the load, but, in addition, he must support the total weight he is lifting.

Notwithstanding the apparent simplicity of the question of haulage by horses, it must be approached by scientific methods. The underlying principles are as real as the principle of gravitation itself, but they must be uncovered by those who are able to analyze forces and trace their resultants. The solution of the question belongs to the engineer, and, as already stated, the public will look to him for guidance in a matter of so much commercial as well as scientific importance.

What is a horse, and why can he pull a greater load at one time than at another? A horse is simply a living machine. He has the power to transport himself from place to place at will, or at the command of his master. A machine of iron or steel, like the locomotive, has power to move only by the application of steam or electricity, under the guidance of man. Its power to pull or haul loads is determined by the conditions under which it is placed and the amount of energy it possesses. For example, a heavy load may be lifted by the common windlass, if the pull is vertically upward. But, if the load be so shifted that the pull is horizontal instead of vertical, as in Fig. 1, the machine must be fastened to the ground or weighted to prevent its slipping. It is so evident that its power is weakened by the direction of draught that the question does not need further discussion.

The principle is the same when applied to the horse, and it is easy even for the unscientific mind to see that the angle of the trace may be such that the animal could not pull a pound beyond his normal weight unless held to the ground by some force or added weight, the alternative being that he would be "lifted from his fore feet."

Again, if the machine, whether it be in the form of a man, horse, or inanimate structure, should be placed upon ice, the coefficient of friction would be very small. If it should require only one pound horizontal pull to overcome the friction due to the weight of the man on the ice, his limit of haulage would be one pound through a similar trace. If ten pounds would overcome the friction of the horse on ice, then the horse, however powerful he might be, could effect only a ten-pound draught. The same rule applies to every condition of road. By this we can readily understand why horses cannot haul the same load upon one road as easily as upon another, and why it is more difficult to pull a load up a hill than along the level. Surely it must be clear that neither a horse nor any inanimate structure would require so much force to pull it *down* an incline as on the level or up hill.

The amount of resistance which a horse can overcome depends upon the following conditions: (1) his own weight; (2) his grip; (3 his height and length; (4) direction of trace; (5) his muscular development, which determines the power to straighten the bent lever represented by his body and hind legs against the two resistances, the vehicle through the trace attached to the shoulder and the hind feet against the ground.

Many erroneous notions exist among men as to the best inclination of the trace for the horse. For instance, if a horse can haul a given load up a given hill with a deep inclination of trace, and cannot do so with a horizontal one, it is generally thought that the former is the better angle. It is, indeed, for that particular hill, but immediately the hill is surmounted it becomes a very bad angle, inasmuch as it involves a great loss of power, as I shall endeavor to prove conclusively.

To pull through a very low trace, or to have a man, or even two or three men, on a horse's back is advisable and even necessary if a horse is expected to haul a load requiring the full force of his muscles at any particular moment—and for the moment, under such conditions, he would be able to draw a much greater load than

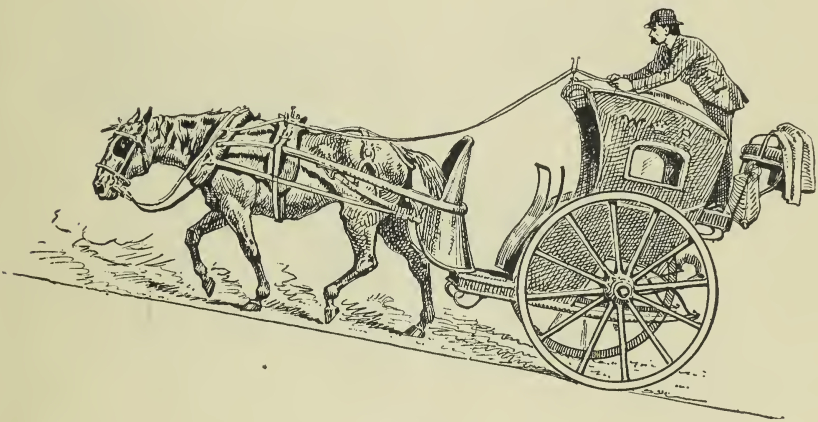


Fig. 4.

without the added weight. But any person can see that the animal could not travel far with any vehicle if he must carry three men on his back in addition to hauling his load.

This point may be illustrated by the hansom cab. When the horse is pulling up a heavy gradient, the driver is often seen to lean forward, thus endeavoring to throw additional weight on the horse's back, knowing from experience that the animal can get along more easily if he carries some of the weight on his back rather than all of it on the wheels. If the driver should care to alight from his box and mount the horse, a very great benefit would be conferred during a heavy pull. If the gradient be a slight one and the road a good one, it would be better for the horse if the

man were to keep his seat and not even lean forward at all, but rather backward. Therefore, to deal justly with our horses, we should not only study cause and effect, but should devise some means by which, automatically, every possible advantage could be given to the horse at all times. Otherwise, there must be a constant waste of energy, tiring the horse prematurely and increasing the chances of his stumbling and falling. It is easy to understand that the efficiency of the horse is lessened and his life shortened if he is continually bearing an unnecessary burden.

I wish now to point out the importance of taking into consideration all the forces which produce a certain effect when the load

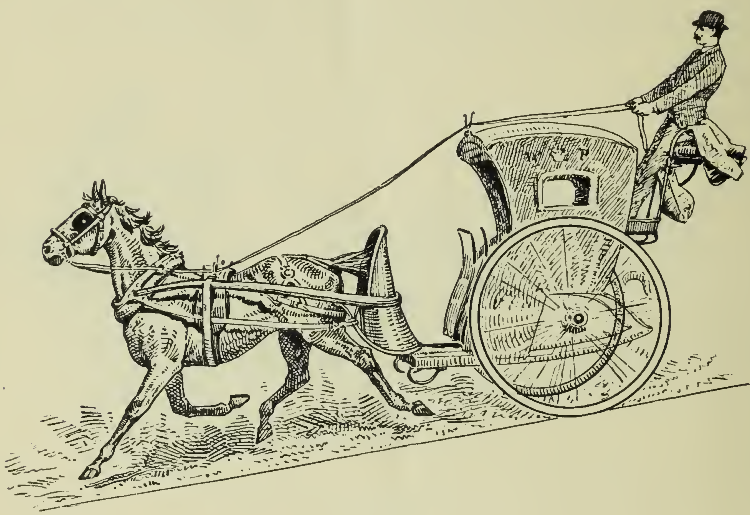


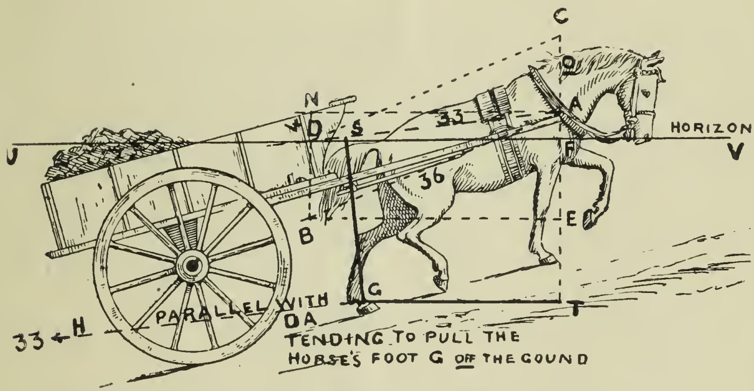
Fig. 5.

is placed in the rear or in the front of the axle. Let us first consider the conditions and the results when the load is placed at the rear end of the cart, as in Fig. 6.

I will omit to plot out the simple levers constituted by the cart itself and the axle as its fulcrum. We will assume that the said lever will produce such a lift at the belly-band as to equal ten pounds at the point A or T. The lift at the belly-band must therefore, be greater than ten pounds, because the long arm of the lever from the centre of the wheel to Y (point of backband) is shorter than to the point of the hame A. We must now understand what it is that the horse is doing. We know that if both the traces should break the load would run backward down hill. But,

as the load is kept moving forward up the hill in spite of its tendency to run backward in obedience to the force of gravitation, we know that a counteracting force must be exerted by the horse through the traces. Inasmuch as we are also aware that the cart would tilt upward at the shafts, were it not for the influence of the belly-band, it must be clear that the horse is exerting a force not necessary to the mere pulling of the cart. He is holding down the shafts with a force at the belly-band equal to ten pounds at A.

Now let us suppose that he is exerting a force of 36 lbs. through AB in a line from the hame to the centre of the wheel. Then let AC represent the vertical depression necessary to hold



RESULTANT of COMPONENTS AB & AC is AD, or ND ADDED TO HORSE'S WEIGHT, ND EQUALS 4 TAKEN FROM THE LOAD AND CARRIED BY THE HORSE

FIG. 6.

down the shafts. Since AB and AC are the forces necessary to produce motion, by completing the parallelogram $ACDB$ we find that AD represents the resultant of the forces AC and AB. Thus we determine one arm of the lever, GS, acting against GT, the other arm. GS is a line drawn at right angles from the resolved angle of force AD.

Let us make it clear that if the load had been balanced on the axle, then, regardless of the angle of trace or hame-chain, the virtual angle of draught exerted would be through AB to the centre of the wheel. Then a line at right angles with AB to G would have been the short arm of the lever, which would have enabled the horse to have pulled a much greater load than possible by the longer arm, GS. But, due to the load being behind the axle, the forward weight

of the animal is reduced by the lift of the shafts at the point A, and the result is the same as if the traces had been put up at the point D, and the load, with a 33-lb. pull through such a trace, would be exactly balanced and no lift at that moment would be exerted at the belly-band. Neither would there be any depression at the backband, although the trace would be so much above the centre of the wheel. In other words, the tendency of the load to rotate backward would, by such a trace (AD, with a 33-lb. pull), be counteracted. There would be equilibrium, and the horse, so far as his power to pull is concerned, would be acting under the same conditions as though he had the lift at the belly-band and his trace at the centre of the wheel.

A resultant pull of 33 lbs. through AD is equal to the thrust on horse's hind foot in the direction HG, tending, as will be observed, to draw the animal's foot off from, instead of into, the ground, thus causing him to slip sooner than if the resultant had been either parallel with the road, or, especially, if it had been digging into the ground. This resultant ought now to be treated as a component, together with the horse's natural and added weight on hind feet due to the pull and the gradient. [Complete diagrams on application to the author.]

Let UV represent the horizon passing through the point D. If DA represents 33 lbs., then FA will represent 4 lbs., so that 4 lbs. must be added to the horse's natural weight by the pull AD. Or, if the pull through the trace AB is 36 lbs., then, drawing BE parallel with the horizon UV, EA (14 lbs.) will represent the depression due to a 36-lb. pull through AB. But, when the lift due to the shafts, 10 lbs., is deducted from the depression of 14 lbs., there remains as before an increased weight of 4 lbs. on the horse.

But when the same horse is pulling with the same force upon a level as in Fig. 7, we find that results are very different from those when pulling upon an incline. Let PA be the direction from the hame to the centre of the wheel and represent a 36l-b. pull. The load having been moved farther to the rear, the lift at the belly-band is still 10 lbs. at P—the load is moved backward to shift the centre of gravity. The resultant of the two components PA and PB is PC, and PC now equals about 35.9 lbs., whereas the resultant AD in Fig. 6 is only 33 lbs., or 2.9 lbs. less than on the level. It will now be found that 36 lbs. pull through PA will increase the horse's weight 4.5 pounds, represented by PO, which is determined by drawing AO from A parallel with the horizon,

cutting the line of gravity PE. But, as the disposition of the load is such that 10 lbs. are taken from the horse, it is obvious that, if only 4.5 lbs. are put back by the said pull of 36 lbs., the horse has still 5.5 lbs. less than his natural weight in Fig. 7, while in Fig. 6 he has 4 lbs. more than his natural weight.

It is essential that we should know why this difference is brought about; otherwise, we should not know why horses have greater difficulty in climbing hills with loads than travelling on the level Neither could we have an intelligent idea how to mitigate the evil, or how to assist the animal in the duties he is called upon to per-

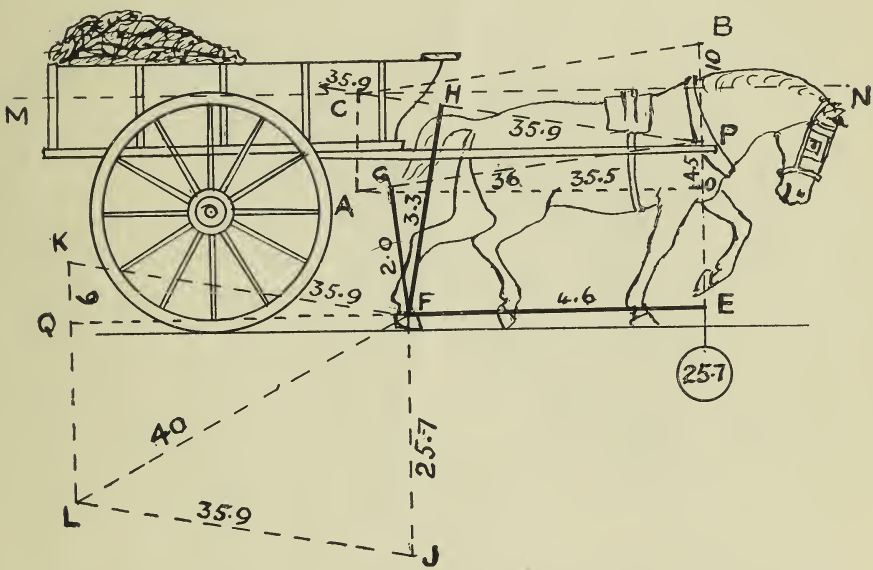


Fig. 7.

form. In all cases it is absolutely necessary that we should know, not only the pull through the trace, which the horse is exerting, but we must know the exact force exerted by the animal, either through the backband or the belly-band, according to the disposition of the load. The one or the other of these forces is of just as much importance as the pull through the trace. And yet, strange to say, they have been practically ignored in the past, with lamentable results.

Inasmuch as these forces are continually changing, due to the inequalities of the road over which the horse is travelling and to the strides of the horse, they must not be considered as constant, although

no perceptible change is taking place. They exist only momentarily, varying in proportion to the irregularities of the roadway or the unsteadiness of the gait of the horse. These irregularities intensify and diminish the lift and depression very much for and against the horse; to such a degree even, that, should he happen to get his propelling foot upon a hard or slippery surface at the moment when the forces referred to are against him, he slips and receives a strain or is thrown.

If the load be shifted to the front end of the cart, as indicated in Fig. 8, the resultant of the forces PJ and PK lies in the direc-

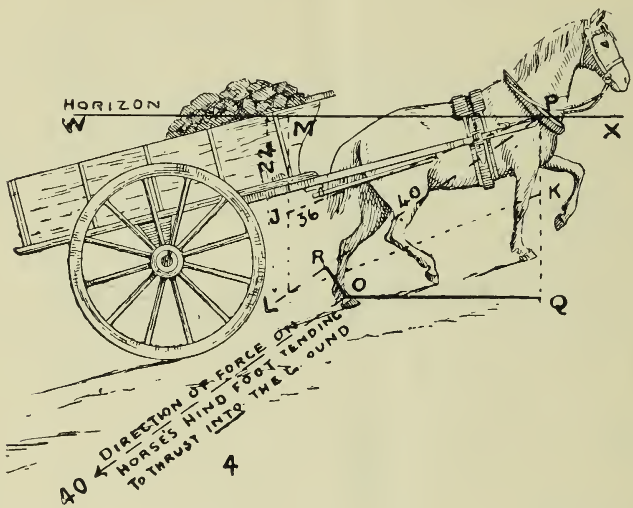


Fig. 8.

tion of PL, and the added weight on the horse is 22 lbs. instead o 4 lbs. as in Fig. 6, tending to thrust his hind foot into the ground at O, and he is able to pull 40 lbs. as against 33 lbs. under the conditions indicated in Fig. 6.

A word now as to the difference between the resultants when pulling up a gradient and on a level plain, the latter being soft or stony ground requiring exactly the same pull through the trace as when climbing the gradient. It will be observed in Fig. 6 that the point of application of force A (the hame) is above the horizontal line UV, drawn through the point D, this being the point at which the traces might be fixed with an advantage equal to having them attached to the axle when the given lift is exerted at A, with a lift at the belly-band as set forth; whereas P, the point

of application of force in Fig. 7, is now much below the horizontal line *MN*, drawn through the point *C* on the resultant, or virtual line of draught. Therefore, if we now compare the triangles of forces, *ABE* (Fig. 6) and *PAO* (Fig. 7), we shall find a great difference. *AB* and *PA* represent the pull through the traces, and, inasmuch as they are not at the same angle with the horizon, although the force in each is precisely the same—viz., 36 lbs.—the result upon the horse is quite different.

If *AB* in Fig. 6 represents a 36-lb. pull, and *AC* a 10-lb. lift, then *AD* (33 lbs.) is the resultant direction of force applied by the animal. Now it will be found that a 36-lb. pull through *AB*, together with a lift of 10 lbs. through *AC* or a pull of 33 lbs. through *AD*, will both be effective in lifting 2.6 lbs. from the horse's fore quarters.

The question has been asked, "Should the horse support the vehicle, or the vehicle the horse?" I will refer to the bicyclist in answer. It is obviously clear to all that the man can travel very much farther and easier when riding his machine than if he were to walk and carry it. In like manner, on similar roads, where resistance to traction is small, it is equally easy for the horse, if at such times the vehicle is made to carry as much of the horse's weight as possible. But while it is clearly right for the bicycle to carry the man on a hard and level road, the condition and the inclination of the road might be such as to make it actually necessary for him to get off and carry a part or the whole of his machine The same principle will apply to the horse and his load.

In further elucidation of this question, I will repeat the results of some experiments. Having hired an out-porter with his baggage-cart, I borrowed three sacks of iron bolts, weighing 112 lbs. each. The cart weighed 70 lbs. and the man 168 lbs. In the first experiment the load was disposed as in Fig. 9. Attaching a dynamometer to the shafts at point *P*, I found it required 110 lbs. pressure, bearing vertically downward, to prevent the shafts from being thrown up into the air. To counteract this force, a weight of 110 lbs. must, of course, have been taken from the man. Consequently, in his effort to thrust the 3 cwt. up the hill, a gradient of 1 in 12 on an ordinary roadway, he failed completely to move it away from the scotches placed to prevent the vehicle from running backward.

Mr. James Dredge, Honorary Member of your Society and one of the honorary Presidents of this Engineering Congress, when he

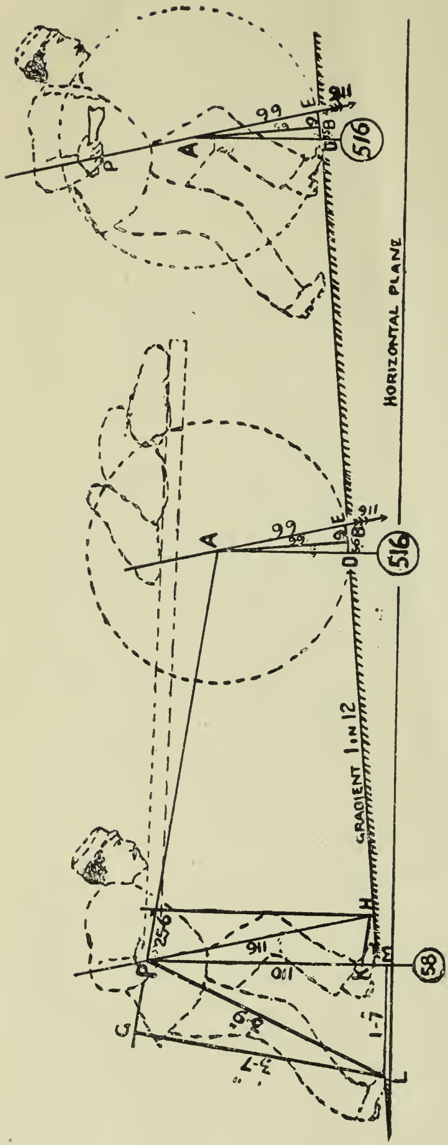


Fig. 10.

Fig. 9.

Fig. 9 is no stretch of imagination, but taken from life.

saw my four original diagrams, kindly and very wisely suggested that another, showing the load still farther from the man, would entirely suspend him in the air, and thus make it unmistakably clear that the man would have no possible control over the load whatever. Such a diagram is produced in Fig. 11.

In my second experiment I moved the sacks of bolts nearer to the man, and added to their weight seven boys—all there were about—as illustrated in Fig. 12. Again I asked the man if he could move the increased load on the same hill and from the same spot. He made the effort, and, to his own surprise as well as that of others, he succeeded, walking up the hill with the 7-cwt. load, although in the first experiment he could not manage even the 3 cwt.

The results of these experiments are somewhat startling to many people. This ought not to be the case, since the results, like all other phenomena, are governed by law, and not by chance. When we understand the law there is nothing whatever to marvel at.

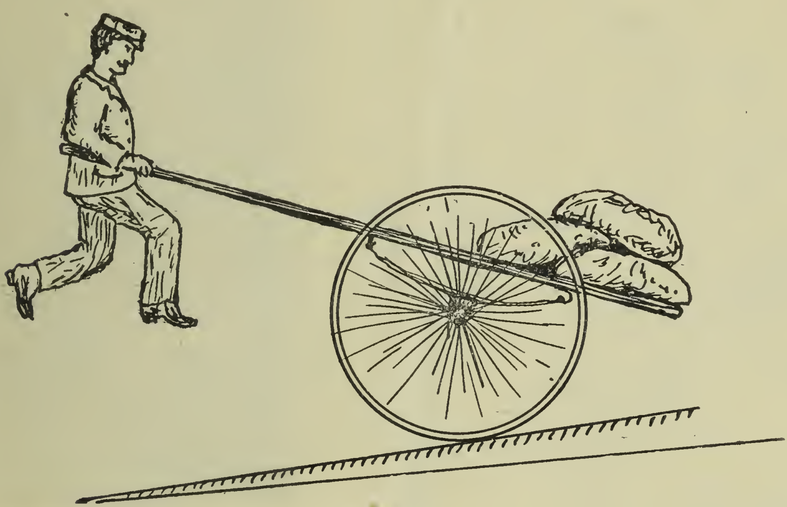


FIG. 11.

Let us examine the conditions, and see why the man could not move the 3 cwt. in the first experiment, but could move more than double the weight on the same gradient in the second experiment In the first case the load had the greater mechanical advantage, and the man was compelled to submit to the greater power. I have said that 110 lbs. of the man's weight were required to prevent the shafts from being tilted. Thus of his natural weight only 58 lbs. remained on his feet. This weight, even if the man's feet were spiked to prevent slipping, acting upon the lever *LM* (Fig. 9), which was 1 foot 7 inches long, against *LG*, 3 feet 7 inches long, could only effect a thrust through *PA* equal to 25.6 lbs. This force was totally inadequate to compete with the load of 336 plus

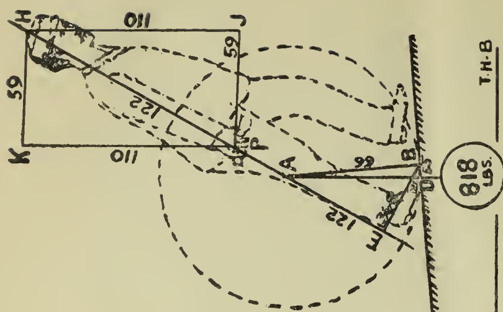


Fig. 13.

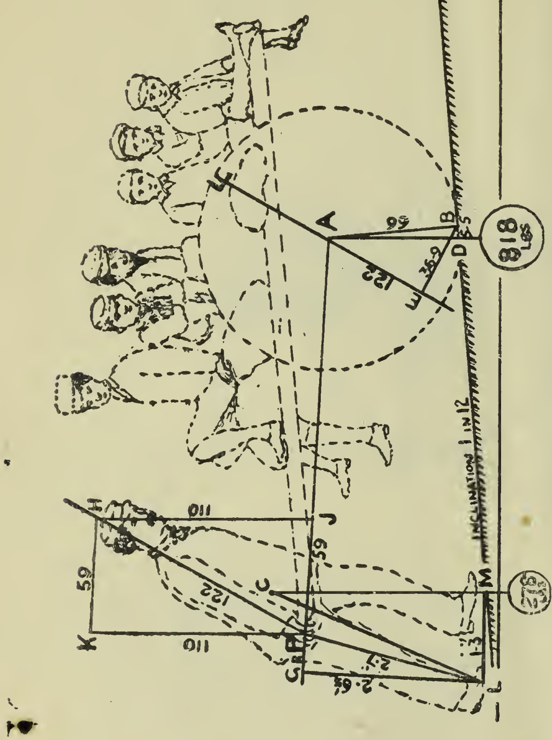
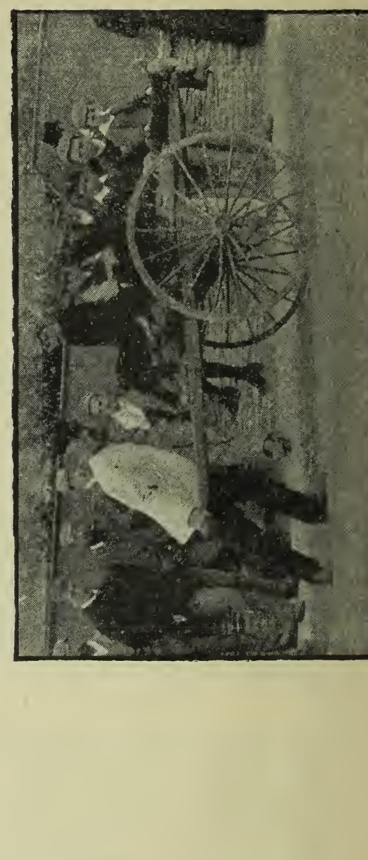


Fig. 12.



From which Fig. 12 is produced (from life).

70 lbs. (the latter the weight of the cart) plus 110 lbs. (the man's weight), a total load of 516 lbs. on a gradient of 1 in 12. Even if the man had been thrusting in a line parallel with the plane, thus getting the advantage of the full leverage of the wheel, he would have required a force of 43 lbs. through that line. However, he was not thrusting parallel with the plane, but obliquely downward;

therefore even still more of his weight than the 110 lbs. was placed upon the wheel by such a declining thrust. The resultant force due to the components PK (110 lbs.) and PJ (25.6 lbs.) was equal to one force of 116 lbs. in the direction of PH. So that, if the gross load of the bolts and cart (336 lbs. plus 70 lbs.), 406 lbs., were balanced on the wheels, and the man were to thrust directly through the centre of the wheels in a direction AE, parallel with PH, the effect, both upon the wheel and upon the man's foot, would be *precisely equal.*

Again, if a pair of wheels weighing 406 lbs., as in Fig. 10, were resting upon the incline, and the man were so thoughtless as to believe that he could either prevent the wheels from running backward, or that he could thrust them forward by advancing and practically lying down upon them, he would find himself very much mistaken. And yet there would not be the slightest difference in the result as between the efforts indicated in Figs. 9 and 10.

Let us now see what takes place in the second experiment, illustrated in Fig. 12. Although the load is more than double what it was in the first experiment, the man, instead of being partly supported by the vehicle, is supporting 110 lbs. of the load, which consists of 336 lbs. (the bolts) plus 70 lbs. (the cart) plus 412 lbs. (the boys), equal to 818 lbs. minus 110 lbs. supported by the man. The difference, 708 lbs., only requires a force through PA equal to 59 lbs., obtained by the lever LM acting against LG, the former being 1 foot 3 inches in length, and the latter 2 feet 6½ inches in length, this force being represented by PJ, while PK represents the vertical lift of 110 lbs. by the man in the act of supporting the shafts.

By completing the parallelogram $PKHJ$, we find that the diagonal PH gives us the magnitude and direction of the resultant force due to the two components PJ and PK, which is 122 lbs. in a line with the man's arms (which would naturally be the case with such a force).

Again, if we draw EF parallel with PH and through the centre of the wheel, and draw a line BE from the periphery of the wheel where it touches the ground, at right angles with the force EF, then EB will give us one arm of a lever constituted by the wheel, and a horizontal line drawn from B to the line of gravitation will give us the other arm of the lever, BD.

While EB equals 36.4 inches in length, BD equals 5.5 inches. So that, if the total load of 818 lbs. were resting upon the wheel

and the man were to pull directly from A to F, he would then move the load *just* as easily and with precisely the same effect upon his feet and arms as when exerting his forces at the end of the shafts, or as if he were pulling at the weighted wheels from A to P, and the parallelogram $PKHJ$ in Fig. 13 is exactly equal to the parallelogram in Fig. 12. The difference between the two diagrams shown in Figs. 10 and 13 is very marked. So is the difference between what the man can do in one way and the other.

Again, it has been claimed that "when a cart is properly loaded a very considerable part of the burden is made to rest upon the horse, and this addition to his weight *tends* to increase his draught power."

If the author of such a statement were compelled to transport a 4-cwt. load over a distance of, say, five or six miles a day, and his master were to insist upon having the load so distributed as that a very "considerable portion," say 1 cwt., rested either upon his hands or upon his shoulders, I appeal to you, would not every one of you be ready to cry "shame" upon such a cruel master? Would he ever again, after his first half-day's work, commit himself to such an amazing statement as that a horse, any more than a man, should be compelled to carry such a burden except when absolutely necessary to assist him when climbing, as in Fig. 12?

I think you will agree with me that such a person, equally with the costermonger, would prefer to recline upon his vehicle rather than be compelled to carry any portion of the vehicle or load when travelling on hard, level roads. If this is clear to you, it is obvious that the vehicle should undoubtedly be caused to render the horse every possible relief by supporting him as much as circumstances will allow, no matter whether it be a heavy cart or sprightly carriage horse.

I should add, before leaving this part of my subject, that the lighter the load the more the vehicle ought to support the horse. When, however, the load increases, the horse ought gradually to lose that support until, with a very excessive load, he ought to support a part of the vehicle himself. This, of course, is a very different thing to the contention that a poor cart-horse, because he travels slowly, should *invariably* support "a very considerable" portion of the load. There is one point, however, that I wish to emphasize. It is this! A load which a horse can draw up any ordinary gradient should never require the horse to support any part of either his vehicle or the load on a hard, level road.

I will now proceed to a discussion of the question as to what should take place when a horse is climbing a gradient. In this case, with a heavy load it is necessary that the horse should support a part of the vehicle. We all know that horses cannot haul as heavy loads up a hill as they can on a level plain, but there are many erroneous notions as to the cause. For example, one of the cleverest practical and theoretical men on this subject has made this statement: "It has been properly observed that horses lose part of their power in drawing up hill because a portion of their weight is transferred from their fore to their hind quarters." And again, he says: "From what has already been said on this subject, it follows that placing the point of traction below the horizontal line is advantageous to the horse in drawing up hill, because it adds to his weight at the time when he loses force by having the centre of gravity of his body thrown backward by his inclined position on a hill."

It is obvious that the speaker did not understand this part of his subject, for he is entirely wrong. I make the statement at the risk of being considered dogmatic, but I know the facts will sustain me, as I could easily prove to you did time permit. Before proceeding further, I would briefly call your attention to what is known as the limit of the "angle of repose." If I place a body upon an incline plane and it remains at rest, it is understood to be within the angle of repose; but, if the incline should be increased to such an angle that the body will not rest upon the plane, but will slip down, it is then said to be outside the angle of repose. If this part of the subject had been properly understood in its bearing upon the question at issue, then Mr. Edgeworth would not thus have committed himself.

Some experiments made by Captain Shaw of the Metropolitan Fire Brigade, London, might easily be made to prove the fallacy of the position taken by Mr. Edgeworth. I will only relate the nature of those experiments. It was contended by certain parties that a horse could haul a ton load up a given hill, and Captain Shaw was made referee. The load was made up of twenty sacks of earth, each weighing 1 cwt. The horse tried to haul this load in a two-wheeled cart to which he was attached, but signally failed to get up the hill. Some one suggested that the load was not properly distributed, and two sacks were taken from the cart and placed on the horse's back. The horse tried again, and this time succeeded in climbing the hill. But Captain Shaw gave a verdict

against the horse on the ground that he did not draw the total load, but pulled 18 cwt. and carried 2 cwt. For some reason the verdict did not satisfy even the judge, and he determined to repeat the experiments, but instead of 20 sacks he would use 22. On the following day the horse was required to make the effort to haul the 20 sacks as in the first experiment, but again he failed. Then the two extra sacks were placed on the horse's back. The result was, as the captain afterward told me, the horse climbed the hill with as much ease, apparently, as he did on the previous day with 18 sacks in the cart and 2 on his back.*

The additional weight on the horse's back, together with the pull through the hame-chains, virtually gave the horse a better angle of draught. Captain Shaw was wrong when he said the horse did not pull the load in the second experiment. If he pulled it in one case he pulled it in another.

If there is any difference between pulling and thrusting, a horse does not *pull* at any time; he *thrusts.* The collar and traces are no part of the horse any more than the shafts are. The collar is only a suitable contrivance for the horse to put his shoulders against, so that he can thrust without hurting himself. It does not matter whether the horse thrusts at one angle or another—it is a thrust. But the angle of this thrust depends entirely upon circumstances; it may be a bad one or a good one. If the load is heavy and difficult to move, and the horse is compelled to effect a horizontal thrust and thus not be able to increase his grip and mechanical conditions, he fails. But if the conditions are such that some of the weight is actually removed from the load and placed on the horse, it is only equal to allowing his thrust to be an obliquely upward one, whereby the transference is got by the thrust.

I wish next to relate to you some experiments with a cripple by which he was enabled to haul a 7-cwt. load, although he could not previously have walked a yard to save his life, without his crutches or some such aid.

About three years ago I asserted the possibility of enabling a cripple, who could not possibly walk a yard without assistance, not only to walk but to take with him a loaded wagon weighing from 6 to 7 cwt. Such a man came to me, an engine driver, who, in the year 1879, had both legs cut off, one above and the other below

* Diagrams of these experiments may be had on application to the author of this paper.

the knee. He had cork legs, and could only get about with the aid of crutches or a machine.

I yoked him to the shafts of a specially fitted wagon, one that I use for experimental purposes. When he was yoked I took away his crutches and he walked away with my wagon, which contained a gross load of 6 to 7 cwt., greatly to the astonishment of those who witnessed the experiment.

But there was nothing marvellous in the result. There was only an application of a well-known mechanical law, one of which the costermonger makes use every day of his life. The costermonger seeks and actually finds rest in the performance of his work, under certain conditions of road, in hauling his cart; it is actually *easier* to take the vehicle with him than to travel without it, at certain times.

A babe that has not the strength either to walk or to stand alone can actually move fairly heavy chairs about the floor, especially if they are mounted on wheels or casters. The babe, like the cripple, finds it necessary only to recline against the chair or the vehicle, and the falling tendency of the one or the other overcomes its resistance and motion results. The babe or the cripple needs only to obey the motion, keeping a suitable attitude by the aid of the chair or the machine. The result is precisely what every man seeks when he has any hauling to do.

The better to impress the force of this illustration, it might be well to point out the fact that it is with the greatest difficulty a man can stand quite still for two hours, but he can walk about for eight or ten hours. The natural restoration of energy is so regular and so complete that we can lead an active life of fourteen to sixteen hours' daily labor, with six to eight hours' intervening rest. Exhausted energy is regularly restored, and we are always ready for the new day's work.

A man can haul a loaded vehicle, weighing 5 or 6 cwt., many miles over a level road more easily than he can stand on the street corners with his hands in his pockets. In this case the principle is the same as that which enables a man to climb a gradient with a bicycle more easily than he can alone. So, too, a man can walk farther and more easily with a walking-stick than he can without it. The same thing is true of the nurse-girl with her perambulator and the boy with his go-cart. The same advantages are secured by the use of the hand-rail in ascending and descending stairs.

In these and in innumerable other instances the muscles of the

arms are brought into action unconsciously to aid the legs. We cannot stand in the streets without ridding ourselves of any parcel we may be carrying. When standing we involuntarily lean upon our sticks, a table, wall, or any convenient object. We seek to relieve the muscles of the legs, which have been doing most of the work. If we have been sitting, we stand to relieve other muscles. We sit after walking or standing. In our beds we shift from one side of our bodies to the other, or to our backs. In short, we are

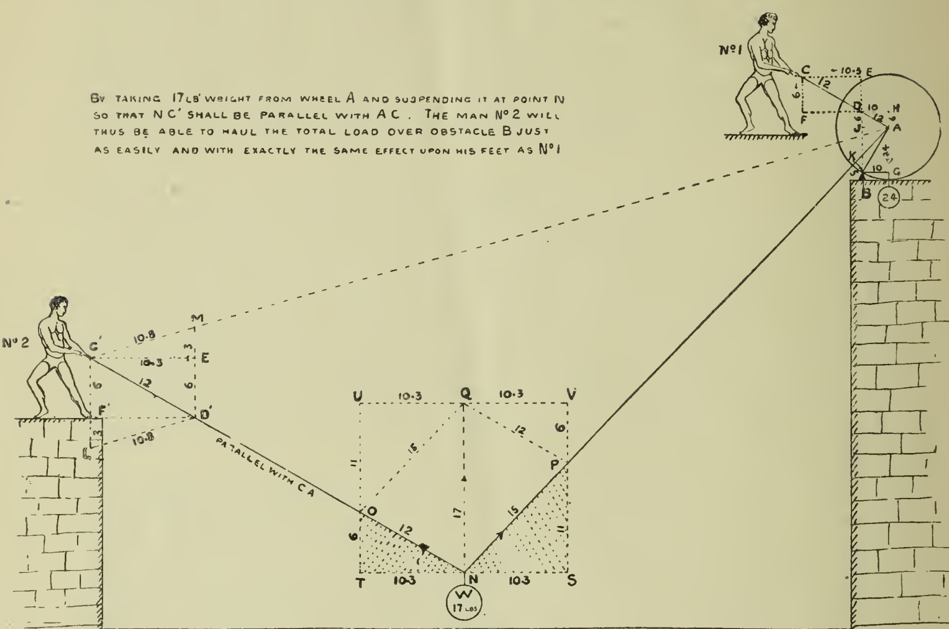


FIG. 18.

always resorting to methods of relief which relaxation of muscles affords.

Although we have been following these practices from the very day of our birth, we have kept on yoking our horses, generation after generation, by methods which compel them, in the shafts of a four-wheeled wagon, to rest their entire weight on their feet. They can neither sit nor lie down, nor relieve their leg muscles, except, as is often seen, by resting their heads upon carts or other support in front of them; this affords some relief to the legs. It is not uncommon to see a horse shifting his weight from one leg to another. When tired, the horse shows the same rest-

lessness that a man does. Men are continually moving, resting first on one foot and then on the other, in search of relief. Generally they can sit down, but horses cannot without being smartly beaten for the effort to relieve themselves.

In Fig. 18 we have an illustration of an interesting principle, concerning the action of the effort in overcoming an obstacle in the path of a wheel. Its load consists of wire coiled around its axle, and it requires a force of 12 lbs. through AC at right angles with BA to raise it over the obstacle B. By such a pull the man No. 1 would increase his natural weight 6 lbs. (CF), and would exert a horizontal force of 10.3 lbs. (CE). For some reason or other it may be necessary that the man should be at a much lower elevation than the wheel, and, say, 1 or even 20 miles away from it. Let this be as it may. If you uncoil the wire,

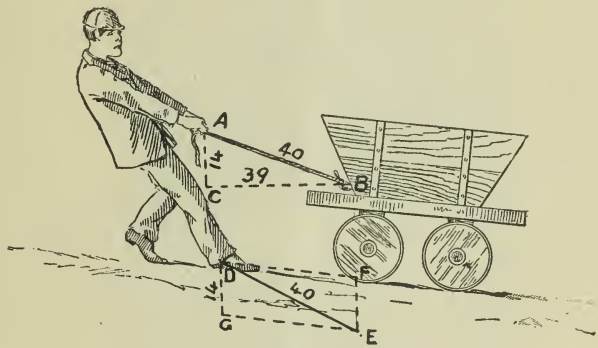


FIG. 19.

which constitutes the load, so that the man can reach one end of it (you may uncoil as much of the wire as you please, so long as its weight does not increase the weight of the man No. 2 more than 6 lbs.), the man No. 2 can rotate the wheel as easily as if he were in the place of No. 1. The truth of this assertion is ascertained by the parallelograms as shown in the figures referred to. If the weight of the uncoiled wire should not be sufficient to increase the weight of man No. 2 to that of No. 1, then an added weight, W, might be attached, but *this* added weight *must* be taken *from the load* on the wheels and *not* be an independent load.

Fig. 19 represents a boy endeavoring to haul a truck up a gradient by means of a trace, AB. He finds the task impossible, because 40 lbs. is as much as he can exert through the trace without slipping. By exerting 40 lbs. through such an angle with the horizon,

he adds only 14 lbs. to his natural weight. The resultant thrust on the ground by his right foot (which will now be doing practically all the work) is in the direction *DE*, which overcomes the resistance of his own and the added weight on the road. But, if the boy gets behind the truck and exerts his forces as an elephant does his (Fig. 20), and if he were to lift 50 lbs. with his hands, exerting 39 lbs. through *EF*, the resultant force on his rear foot (assuming it to be doing all the work in this case) would be 64 lbs. in the direction *AD*, which is a very different angle to that of *DE* (Fig. 19). The boy can thus exert to the limit of his muscular capacity without fear of slipping. In fact, if he were to lift, say, 98 lbs. through *GE* and still exert only a 39-lb. thrust through *FE*, the resultant through his legs would be 110 lbs. in the direction *EC*.

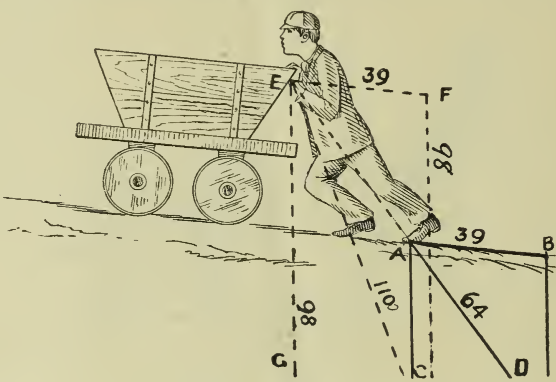


FIG. 20.

I was once told by a professor that the draught power of a horse depended more upon the development of his muscles than upon his bodily weight, and that a light thoroughbred horse, with well-developed muscles, could haul a greater load than a much heavier horse with muscles not so well developed. This statement I contradicted, asserting that, apart from the extra momentum which the light horse could throw into the traces, the heavier horse could always effect the strongest pull, provided all conditions, excepting those of muscle and weight, were equal. The build and the disposition of a horse will often deceive us if we are not on our guard. Even one nail in the shoe of the lighter and weaker horse may be the means of misleading us.

Very soon after my controversy with the professor I approached Mr. Sandow, the strong man, who had just created a great sensation

in London by proving himself stronger than Samson—"the strongest man on earth." He kindly consented to allow me to try any experiments I chose with him to elucidate my views upon the use and importance of muscular development. Such development cannot enable a horse or a man to make a heavier *steady* pull, but it will enable him to maintain that pull through a much greater space of time, and effect a stronger jerk, imparting greater momentum than could be given by the weaker horse or man.

I placed Sandow on a pivoted foot-board, with an adjustable block to prevent his assuming any other position than the one in

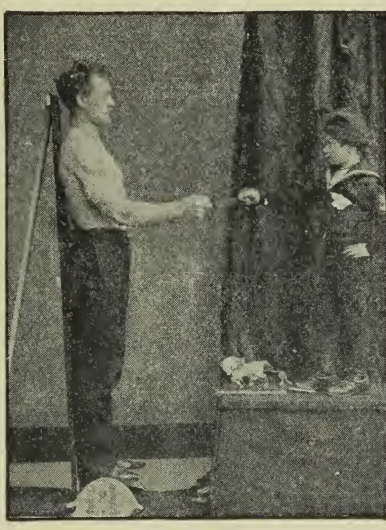


Fig. 21.

which I placed him. In the position indicated in Fig. 21, Sandow, with all his muscular development, could not exert a steady pull of more than 2 pounds against my little boy, then 6 years of age But when I allowed him to assume the position shown in Fig. 22 he could exert a 40-pound pull against myself, but that was the limit. In that position I could overcome all the resistance he could effect. But, when in the position shown in Fig. 23, I could not outdo him. On the contrary, I might have fagged myself to death by pulling, while he would have been little or none the worse for the effort. His muscles were so well developed that they could endure my pull very much longer than my muscles could maintain it.

Were Sandow to lie down flat and exert his forces in a direct line through his body, there is not a horse in Chicago that could outpull him, since he could then exert the full power of his muscles in a direct line with his body, without being hampered by conditions which, in the preceding experiments, prevented the possibility of his bringing into play the forces he possessed.

Not only are our horses compelled to exert themselves under unfavorable mechanical conditions, on the lines set forth in Figs. 21. 22, and 23, when they are required to haul heavy loads, but they suffer even a greater cruelty at our hands at such times as when

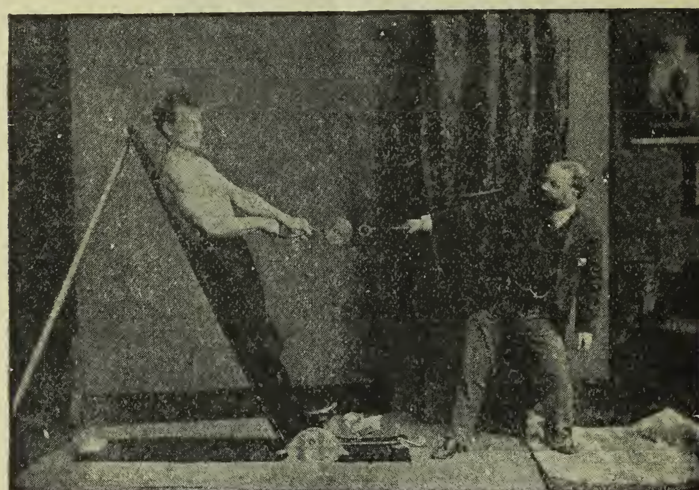


Fig. 22.

the vehicle requires little or no pulling. This I will endeavor to make clear to you by reference to the structure and movement of the locomotive engine, which are familiar to the members of this congress.

Let us, for example, mount a locomotive upon incomplete wheels —spoke-wheels, if they may so be called—wheels without a periphery, and suppose the extremities of the spokes to be 2 feet apart and the spokes themselves 4 feet long. If the total weight of the engine (50 tons) should be resting upon two of these spokes, it would require a horizontal force of more than 25 *tons* at the centre of the wheel to produce motion in that engine on a level plane, with no tender attached. Yet, if the same load were resting upon a

perfectly round wheel, it would move on the application of a force of about 10 cwt., or considerably less than that amount.

Therefore, when we realize the *fact*—for it is a *fact*, whether you believe it or not—that our horses are compelled not only to deal *continuously* with their own weight upon their feet, but also with some of the weight of the vehicle, thus they are caused, absolutely unnecessarily, to waste their strength, and life, and energy, just as would be the case with an engine if compelled to work on a polygonal wheel, with sides measuring from one to two feet in length. It becomes obviously clear to all of you that it is

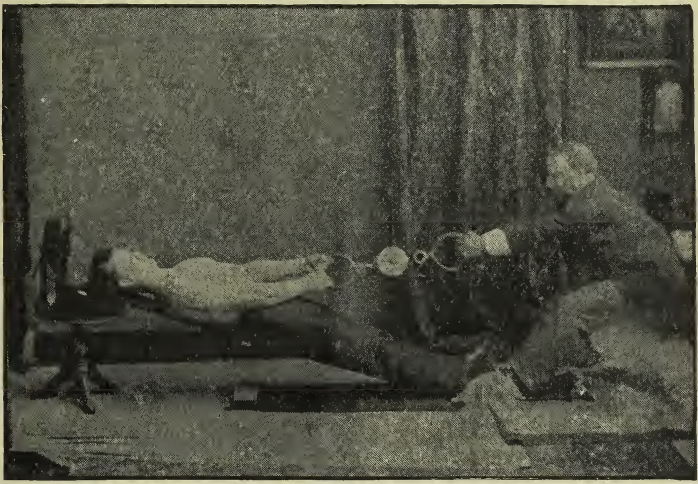


FIG. 23.

no more possible for a horse to carry his centre of gravity parallel with the plain upon which he is running, when he must rotate first upon one leg and then upon another, than it would be possible to get the same steady run of a locomotive engine upon a polygonal wheel as is secured by the present round one.

From this it is plain that the horse is *compelled*, absolutely unnecessarily, to exert himself under conditions such as no engineer in the world would for a moment think of applying to his steam-horse, under which to waste its energies and knock itself to pieces, in, practically, no time. I appeal to you, is there any wonder at our living horses suffering so much by reason of their legs failing them when so brutally knocked about, not only by such unscientific methods of attachment, but by reason of the rough and stony roads

over which they travel? I say, gentlemen, there is NO WONDER, unless, indeed it be, that they bear such treatment so long and so patiently.

We need no further or more forcible example of the vast difference between the two methods of effecting transportation than is contained in a mere reference to what we ourselves can do. Of course, there is no practical difference between the conditions under which a man or a horse transports himself when in the act of walking; both require a great amount of force, as in the case of the engine on polygonal wheels. If a man starts out on a long walk he does very well if he covers 50 miles in a day, but the same man is not only able to transport himself but to take a machine with him and travel more than 400 miles in 24 hours. Further proof of my contention is afforded by the use of pneumatic-tired wheels, which tend to keep the centre of gravity more nearly parallel with the plane.

Be good enough to put the man on polygonal wheels, when you will find that he will have great difficulty in travelling his 50 miles, the distance, of course, depending upon the length of the sides of the wheels. By adopting such means as those described you put the man back to the unfavorable and extravagant method of transportation which hampers him when walking. I do not wish to be understood as complaining of our construction; on the contrary, we are the most perfect of machines, wonderfully conceived, with brains—if we would only use them—to plan not only our own comfort and pleasure, but the comfort of the noble creatures we are here to consider, interests which I believe to have been sadly too long neglected.

Before leaving the question of the locomotive engine, I should have liked very much to have discussed the question as to what *are* and what *are not* its impelling forces, upon which question I hold very different opinions to those which are said to have been accepted as true by engineers for the past thirty or forty years—before dismissing the locomotive, let me give you one or two simple illustrations, which may tend more forcibly to impress my views upon this important feature of our subject.

In Fig. 24 the sphere weighs 5 cwt. In Fig. 25 the square block has the same weight. Now, it would be quite an absurdity seriously to ask any man which of the two bodies (Figs. 24 and 25) he would prefer to roll along the road. In Fig. 24, B is the point of rotation of the wheel A, and the centre of gravity of

the load is directly above it at A, balanced, as it were, and ready to roll either to the right or to the left on the application of the slightest force, provided the wheel is rigid and upon a hard smooth rail.

But the line of resistance in Fig. 25 is CD and must rotate about D, and C, being the centre of gravity, must be literally raised until its altitude is increased from CE in Fig. 25 to GF in Fig. 26 before the load will roll as easily as in Fig. 24. But, to produce motion at all from the position indicated in Fig. 25, there must be exerted a horizontal force through the centre of gravity C equal to 5 cwt. The body would, therefore, remain in its present position forever if its motion depended upon the unaided strength of a man to roll it by a force exerted through its centre of gravity.

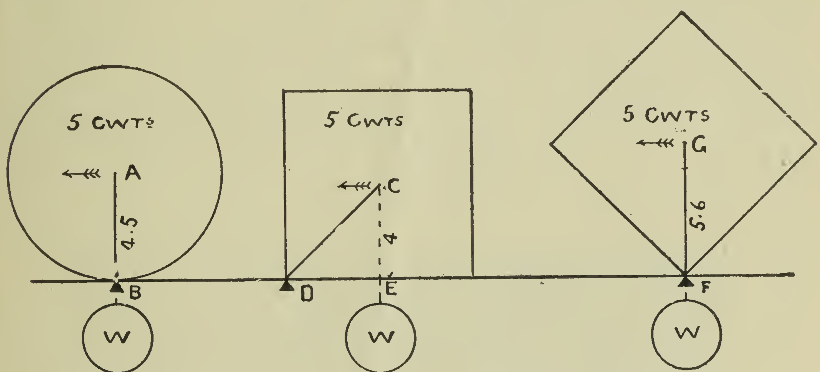


FIG. 24. FIG. 25. FIG. 26.

The result of my investigations is that, having ascertained the fundamental and economic principles involved in the haulage of vehicles and the transportation of living or inanimate matter, I have devised a special contrivance applicable to all kinds of four-wheeled vehicles or sledges, which will, at all times, automatically afford the horse all possible assistance. It does not matter whether he be travelling on smooth, level roads, up hill or down, with a heavy or a light load, he cannot fail to receive a direct advantage from the very moment he is attached to the moment he is detached. The relief is afforded while he is walking, running, or even standing.

The percussion on his feet is reduced at every stride during the day. His muscles are less strained, and his energy is economized

as you would economize the energy of a locomotive. He receives that relief on a level road and while going down hill, and in part while going up hill, that a lady would receive by taking the arms of two gentlemen, one on either side of her. The relief is better felt than expressed. The costermonger and others seek for and obtain it, though they know not what it is. The simple contrivance which I have hit upon, and which gives to the horse all the advantages which men so persistently demand for themselves, is on exhibition at the World's Fair and may be seen and tested in Section "*G* 55," Transportation Building.

INTERESTING EXPERIMENTS WITH AN AMERICAN-MADE BUGGY BELONGING TO THE RIGHT HON. THE EARL OF LONSDALE, WHO HAS DONE MUCH TO FACILITATE MY INVESTIGATIONS.

The buggy is claimed to be a vehicle of 5 lbs. draught on a level road. I prove conclusively it is nearer 15 lbs.

In America, as in England and other countries, there seem to be very incorrect ideas as to the proper method of testing the draught of a carriage. In testing the draught of the buggy in question, I first weighed the shafts at the point where they are held by the backband to ascertain the force which the horse must exert before he begins to pull. I found the weight to be no less than 9 lbs.; therefore, the animal must exert 9 lbs. vertical force to support the shafts alone.

To ascertain beyond a doubt the direction and magnitude of the force required to travel on any given road, tie a small steel spindle across the shafts at *A* (Fig. 27), passing easily through a strip of wood, or other material. Attach one end of this to a dynamometer, *K*, the latter being supported by a stay, *LM*, supported at the rear of a moving vehicle.

By this simple contrivance we transmit all the forces to the buggy which are necessary not only to carry the shafts, but to draw the vehicle along at any required speed, taking care to keep the shafts at about their normal working height. Not only will the strip of wood then indicate *exactly* the angle of traction, but the dynamometer will indicate exactly the amount of force exerted through that angle. (It will be observed that this angle will be continually changing.)

Instantaneous photographs were taken during the progress of the following experiments. The angle of traction is indicated in each instance by *KO*, on a slight up-gradient. Now, apart from

the force registered on the dynamometer, knowing the shafts to weigh 9 lbs. at *A*, set down nine equal parts vertically from *A*, giving us *AD*. Draw *AC* in a line from *A* to the centre of the point of rotation of the shafts, and a line parallel therewith from *D*, cutting a line continued through *KO* to *B*. From the point where *DB* cuts the extended line *KO*, draw *BC* parallel with *DA*, thus

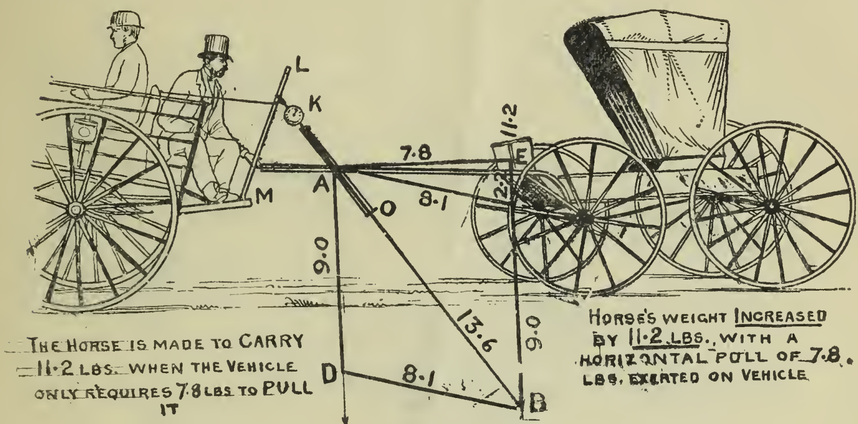
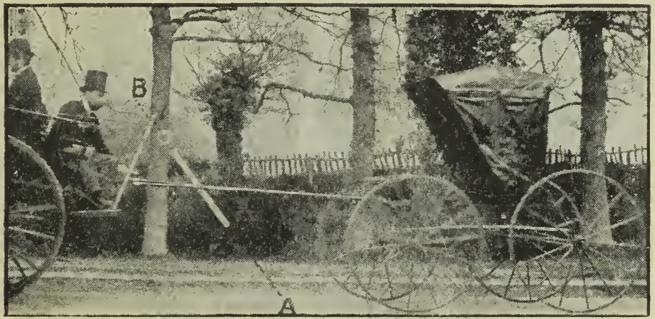


Fig. 27.



From which Fig. 27 is produced.

completing the parallelogram *ACDB*. Then, if *AD* equals one component force of 9 lbs., *AC* will represent another of 8.1 lbs., the resultant of which will be found in the direction and magnitude of the diagonal *AB*. This shows that the exact force exerted by the horse is 13.6 pounds, and gives the angle through which such force is exerted to keep the buggy in motion at that particular moment.

Thus we prove that the angle of draught, instead of being through and in a line with the traces, as most people think, is actually in the direction of the oblique line AB, and that the draught is 13.6 lbs. instead of 5 lbs. as claimed.

This diagram further proves that, with such an oblique force through AB, there *must be* a vertical force in the direction of the

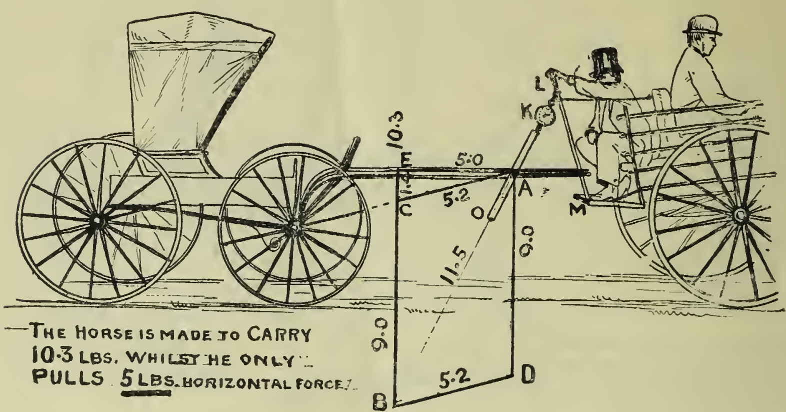
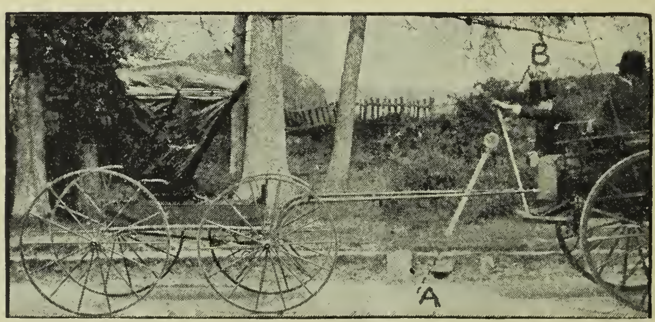


FIG. 28.



From which diagram Fig. 28 is taken.

line BE of 11.2 lbs., transferred from the vehicle to the horse's feet. Therefore, it is clear that the horse is compelled to carry 11.2 lbs. in addition to his own weight. But the costermonger would have carried less than his own weight (very sensibly, too, when resistance was so small). This 11.2 lbs. means that there is about 22 lbs. greater percussion on the animal's feet when travelling only about 4 miles an hour, even on level ground, but consider-

ably more when travelling rapidly. (I regret that I am unable to treat of this part of the subject in this paper.)

Without delaying to explain the action of all the forces indicated in Fig. 28, in which the vehicle is shown to be travelling down a slight grade, we find the obliquity of KO is not so great as when the vehicle was moving in the opposite direction over the same ground.

We now find that AC is equal to 5.2 lbs., AD, the weight of the shafts, remaining the same, the resultant AB, in Fig. 28, is equal to 11.5 lbs. against 13.6 lbs. in the preceding experiment, and that the added weight on the horse, even when he is travelling down hill, is actually increased by the amount BE, or 10.3 lbs.

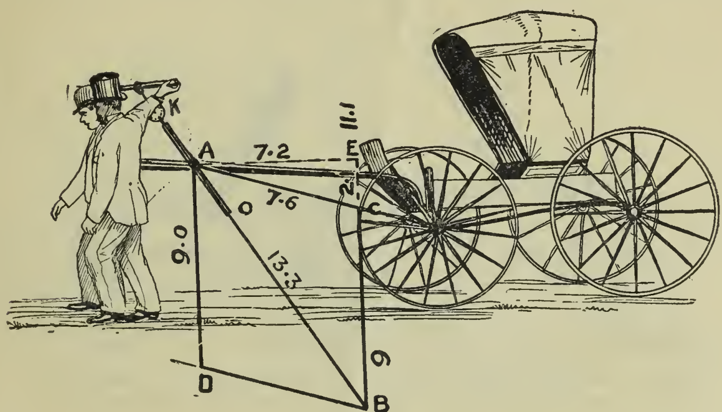
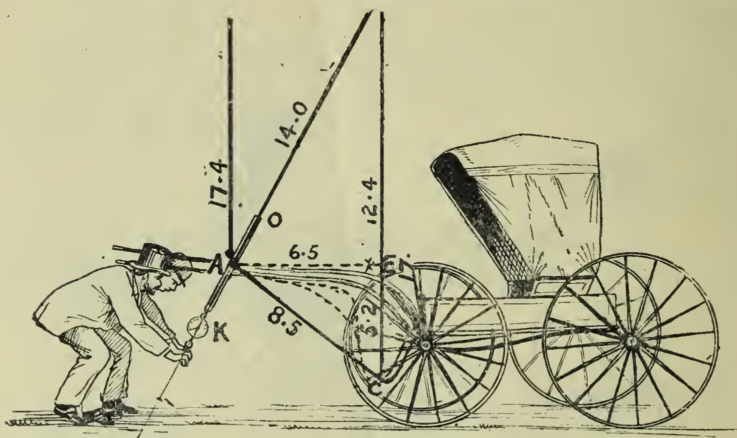


FIG. 29.

Passing hastily to Fig. 29, with the same vehicle drawn by men at a slower rate of speed, we again find that the obliquity of KO is not so great as in Fig. 27 (due, of course, to the slower pace). Here we find AC equal to 7.6 lbs., AD remaining the same. AB, 13.3 lbs., is now the resultant angle, and the magnitude of the force exerted to draw the vehicle—not merely 5 lbs., as shown by easy reasoning.

In Fig. 30 we have quite different results. By means of a special contrivance a lift is effected at the belly-band, or at the point A, equal to 24.1 lbs., so that when the weight of the shafts is deducted from that amount we still have a lift of 15.1 lbs. at the belly-band. To resist this lift, and at the same time produce a forward movement of the vehicle, it is now found that the men must *pull down* at the dynamometer, and that KO is the re-

sultant direction of the components AD (15.1 lbs.) and AC (7.1 lbs.). AB is the magnitude of this force, which is equal to 14 lbs. exerted in the direction from B to A, thus reducing the weight on the men, or the animal pulling, by 15.1 lbs., instead of increasing it as in the preceding experiments, making a difference of 15.1 plus 11.2 minus CE, 2.7 lbs., equal to 23.6 lbs. less weight to be carried on the horse's feet, or a percussion less by 47.2 lbs. at every stride, when the horse is travelling at a speed of four miles an hour. Multiply this by the number of strides he takes in a day divided by four, and you will appreciate the difference in the effect upon



WITH A LIFT OF 26.4 LBS. AT THE BELLY-BAND A, AFTER DEDUCTING WEIGHT OF SHAFTS (9LBS.) WE HAVE STILL A LIFT OF 17.4—5.2= 12.4 LBS. AT A

FIG. 30.

(*Taken from a Photograph*)

the horse, and will see how work is done unnecessarily, energy wasted, and discomfort increased.

To realize the practical effect of the difference between a light and a heavy blow, let us tap gently with our knuckles upon a hard, fixed stone. We feel, perhaps, that we might go on knocking without suffering. But, striking a harder blow, we soon find that we must cease the operation.

Take another illustration, as indicated in Fig. 31, where the forces are applied by a man hauling a cart weighted, as shown, at the rear of the axle. In this case, as in Fig. 30, the dynamometer must pull downward and forward to prevent the shafts from shooting upward, and to cause the vehicle to move forward. In this case we have clearly set before us the conditions which men find from experience to be so conducive to their own comfort. It is to

these conditions I wish to draw your SPECIAL attention, since I believe they are THE ONLY CONDITIONS upon which ECONOMIC HAULAGE CAN POSSIBLY be effected on fairly good roads, and where heavy gradients are not encountered.

In Fig. 31 the load W (67 lbs.) is so disposed that a force F (42.8 lbs.) is required at P, acting vertically downward, to produce equilibrium in the lever PJH, of which J, the centre of the wheel, is the fulcrum. It is obvious that the wheel is supporting not only the 67 lbs., the weight of the boy, besides that of the cart body, but is supporting also 42.8 lbs. of the man's weight; but, mind you, only when the cart is at rest.

To ascertain the angle and magnitude of draught required to

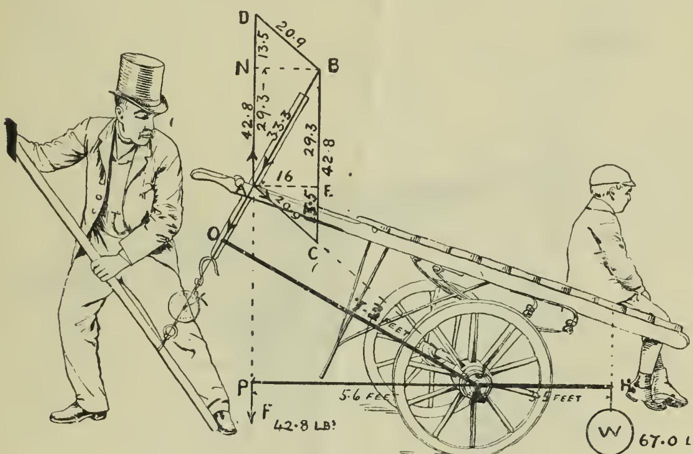


FIG. 31.
(*Taken from a Photograph.*)

haul this load, let us refer again to Fig. 31. The dynamometer K with the slip of wood, as used in the preceding experiment, is again brought into use to prevent the shafts from tilting upward, and to keep them at about the same angle as when hauled by the man in Fig. 32. We find by the parallelograms $ACBD$ and $AEBN$ (Fig. 31) what are the component and resultant forces which are required to produce the desired advance. The force AD (42.8 lbs.) is determined by the disposition of the load on the lever PJH. Let us then set off 42.8 equal parts on the vertical line AD. Draw AC to the centre of the wheel and DB parallel with that line, cutting AB (an extension of the line KO running through the dynamometer), and from B draw BC parallel with AD, thus completing the parallelogram of forces exerted by the man.

Although a vertical force of 42.8 lbs. is required at P to produce equilibrium, the vehicle still at rest, it may seem remarkable that a single force of 33.3 lbs. exerted through BA will not only balance 67 lbs. at H, but will propel the vehicle at the same time. The action of the force AB (33.3 lbs.) may be considered in two ways.

1. BA being the direction and magnitude of that force, if we draw a line from the centre of the wheel J to and at right angles with the extended line BA, cutting it at O, we shall find that OJ represents the leverage which a force, BA, has upon the short arm of the lever JH, and that, as OJ measures 7.3 feet against PJ, 5.6 feet, BA will slightly more than balance 67 lbs. at H, and that, by

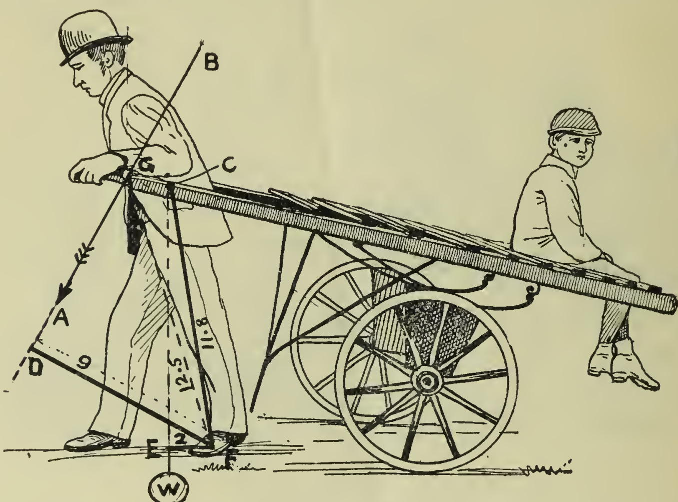


Fig. 32.

reason of the obliquity of BA, a horizontal force of 16 lbs. in the direction from E to A is imparted to the vehicle, which now causes it to move on a slight up-gradient.

2. From the fact that a force of 42.8 lbs., acting vertically upward, is exerted at A by the weight W at H, there does not follow the conclusion that the total weight is taken from the man's feet when the vehicle is at the point of motion, for the simple reason that the vehicle will not run up hill without an external application of force. This force is represented by the component AC, which equals 20 lbs. Well now, to resist a force of 33.3 lbs. through BA in addition to the 42.8 lbs. through AD, it will require another force of 20 lbs. through AC to counteract BA. There-

fore a pull or resistance of 20 lbs. by the vehicle from the centre of the wheel in the direction AC will be effective in bringing CE, 13.5 lbs. of the 42.8 lbs., back on the man's feet when the load is at the point of motion. So that the reduced weight on the man's feet, which he feels to be of such great relief to him, is 29.3 lbs.

By this reasoning it is clear that, although the vehicle, while at rest, might take a given number of pounds from the horse's feet, it depends entirely upon whether the virtual angle of pull is above or below the horse's hame-hook to determine whether the horse's weight is increased or diminished.

As to the effect of added weight upon the feet of a man or a

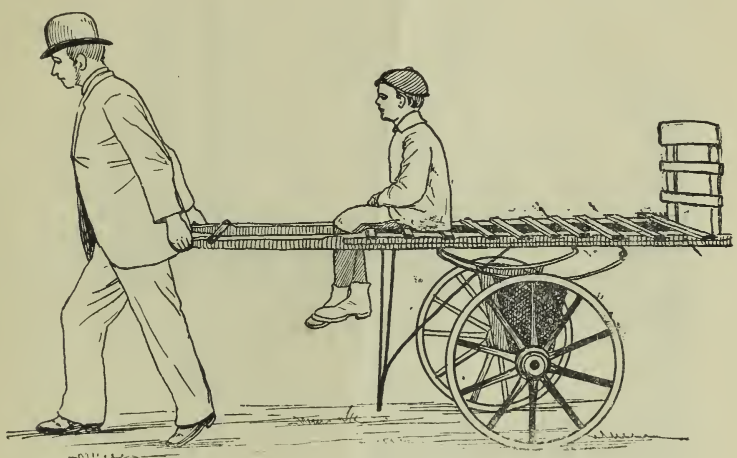


Fig. 33.

horse when travelling, it is seen in the evident and appalling AGONY inflicted upon the carriers of the sedan-chairs at the World's Fair grounds. This is the most HORRIBLE sight to be seen at the World's Fair.

Refer to Figs. 33 and 34, in which the load is represented as consisting of a small boy. Our costermongers would as soon think of flying as to haul him about the streets, placed in the position shown in the illustration. It is to be noticed, in this case, that the man is not bearing half the boy's weight. Then think of the weight of the sedan-chairs, and a 14-stone man within smiling at the misfortune of those who are being almost tortured to death by the weight of his heavy idle bones. It is an act of EXTREME CRUELTY thus to suffer one's self to be carried when there are other and

easier means of transportation, even though one suffer in carrying his own weight upon his wellnigh exhausted muscles.

From the standpoint of commercial advantage, which may appeal more forcibly to the world at large, is there not a most urgent demand that we lessen the burdens placed upon the horse? We have seen that the costermonger, who knows no more than his cart about natural law, when hauling his wares, acts in perfect harmony with natural law and unquestionably in accordance with common sense. When we plot out the forces which this ignorant man brings into action in moving his cart, no matter whether his load be

Fig. 34.

heavy or light, whether he be travelling up hill or down, or upon the level road, the application of the resultant is found to be mathematically correct, notwithstanding the man's absolute ignorance of mathematics. This is not to be wondered at, since man, when a free agent, seeks to obtain all the ease and comfort he can, and when doing his own work is sure to find out the easiest way.

Experience alone has taught the costermonger how to deal with his load and how to relieve himself of unnecessary burdens. It is not a matter of indifference to him where he places his load, or whether he shall push or pull his cart. To him his methods are everything, and he rightly persists in his usage. On the other hand we, who boast of our education and civilization, are acting in

defiance of natural law and common sense by so yoking our horses as to compel them to do their work under conditions such as no man would for a moment consider in the execution of his own work.

Time fails me in my attempt to lay before you hundreds of interesting diagrams, based upon scientific facts, and bearing upon this important subject; therefore, I have tried merely to impress upon you the fact that the subject is one well worthy all the intelligence that can be brought to bear upon it. Although it may relate to the common draught of a horse, it embodies principles which have *never yet been* practically applied, and principles which NO MAN need be ashamed to understand, whether they be applied to the *steam engine*, *steamboat*, horse, or a million other subjects.

I am profoundly impressed with the importance of the subject, and I trust this congress, representing the profession which, more than all others, helps the world on to better things, will give it the consideration it deserves. It may seem a simple matter to aid the horse in his work, and one of no particular importance, because he is a brute and toils at our bidding. On the contrary, as I have shown you, it is a question in which the humanity of man is involved, one which should no longer be permitted to defy scientific principles, and one upon which commercial prosperity so largely depends.